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Physio-chemical Studies of Locally Sourced Non-Edible Oil: Prospective Feedstock for Renewable Diesel Production in Malaysia

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Abstract

Physio-chemical properties of locally available waste cooking oil (WCO), jatropha oil (JO) - *Jatropha curcas*, rubber seed oil (RSO) - *Hevea brasiliensis*, kapok seed oil (KSO) - *Ceiba pentandra* and castor oil (CO) - *Ricinus communis* were characterized to assess and evaluate their potential use as renewable diesel production feedstock in Malaysia. Physio-chemical properties such as density, kinematic viscosity, moisture content, flash point, calorific value, iodine value, acid value and fatty acid composition were determined under standard analytical methods established by American Oil Chemists' Society (AOCS) and American Society for Testing and Materials (ASTM). Among the non-edible oil evaluated, the promising physio-chemical properties of RSO and WCO were found to be most applicable to serve as the raw feedstock due to its low iodine content, high free fatty acid content and high flash point. Furthermore, RSO feedstock can reach up to the capacity of 60 million ton per annum with a total 1.2 million hectares of existing rubber tree plantation in Malaysia, which is approximately 500-fold more than that of the annual waste cooking oil available in Malaysia (0.12 million ton per year). Thus, it can be concluded that RSO has the most promising potential in serving as the raw material for renewable diesel production in Malaysia.

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Keywords: Physio-chemical properties; Non-edible oil ; Prospective feedstock; Renewable diesel

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1. Introduction

Since the advent of industrialization and technological revolution, energy supply has been the primary driving force and fundamental backbone for modern economic growth and development. It supports the provision of all basic necessity of human being, ranges from domestic residential usage, public transportation sector, industrial and commercial activities as well as heavy industrial applications. It is the key determinant of any industrial manufacturing sector performance and the most vital commodities for socioeconomic development of a nation. Industrial manufacturing sectors is the main engine to any nation's economic growth and it often provides a locus to stimulate the growth of other associated activities. Thus, it is imperative for a developing country like Malaysia to unequivocally admit the importance of energy in pursuit of sustainable growth.

Despite the modern urbanization in Malaysia, the industrialization progress has been accompanied with the seeds of environmental impacts in terms of pollution and degradation, all assisted and abetted by the inevitable human innate's aspiration for modern development and better living standards. According to United Nations Development Programme (UNDP), Malaysia was ranked at 26 th worldwide in 2012 in terms of the anthropogenic carbon dioxide, CO2 emission based on its total emission in 2004 [5].Among the Southeast Asian countries, Malaysia is the third largest greenhouse gases emitter after Thailand and Indonesia, contributing a total of 0.62 of the global emission with the average Malaysian contributes 7.7 metric tons of CO^2 per annum [3]. In parallel to the global efforts in reduction of fossil fuel consumption and greenhouse gases emission intensity level, Malaysia pledged its commitment to reduce the nation carbon emission intensity (per GDP) level up to 40% below by 2020 at Copenhagen Climate Change Summit 2009 [22]. Malaysia was, in fact, among the first few Southeast Asian nations to commit such climate responsibility and slot in environmental concerning factors in its long-range economic plans and strategies. In the recent 2015 Conference of Parties (COP21) held in Paris, Malaysia's commitments in promoting sustainable economic development continue to show by committing in reducing greenhouse gas emission by 45% by 2030 as highlighted in the Intended Nationally Determined Contributions (INDC) [26].

In recent years, Malaysia government has intensified their efforts in promoting the use of biofuel for the sustainability of its economic development. So far, only blends of fatty acid methyl esters (FAME) derived from edible palm oil and conventional hydrocarbon based fuels (B5, B7 & B10) are currently available in Malaysia vehicular fuel retail market [2]. The main limitation of biodiesel is its affiliation with the "food-versus-fuel" debate, at which the rising food prices are partially related to the increase of energy crop cultivation over the food crops [23]. Even biodiesel production employs non-edible oil based feedstock available in Malaysia, the pure FAME biodiesel stills owns several limitations to be fully incorporated into the existing diesel engines. Other than FAME biodiesel, hydrogenated derived renewable diesel (HDRD) is one of the prominent fuel of tomorrow due to its excellent fuel qualities and promising environmental benign properties as compared to the FAME. With the cetane number ranges between 70 and 90, HDRD retains a much higher cetane number than that produced from transesterification of triglycerides, rendering it a competitive diesel substitute. The fuel properties are similar to the fossil fuel derived fuel and can be incorporated into the existing transportation engine without any modifications.

In 2011, European world's largest renewable hydrocarbon manufacturer, Neste Oil Corporation has established its third renewable diesel production facility at Tuas, Singapore with the production capacity of 800,000 metric tons renewable diesel per annum [16]. Importing renewable diesel fuels from neighboring country would result in high tariffs and transportation costs, making it less cost competitive to the conventional petroleum based fuel in Malaysia. To circumvent such issue, local production of bio-fuels seems to be the most viable solution, providing the biomass resource can be obtained locally and available in bulk quantities. Using locally available non-edible oil as feedstock would be the desirable alternative without interfering the local food supply chain. In this study, five locally available non-edible oils namely, waste cooking oil (WCO), jatropha oil (JO) - Jatropha curcas, rubber seed oil (RSO) - Hevea brasiliensis, kapok seed oil (KSO) - Ceiba pentandra and castor oil (CO) - Ricinus communis are selected, studied and compared in term of physio-chemical properties in order to determine the most feasible and suitable non-edible oil feedstock for hydrogenated derived renewable diesel production in Malaysia. The availability of non-edible resource will be assessed as well since it is closely associated to the viability of commercializing such fuels production in Malaysia.

2. Materials and Methods

2.1. Materials

The non-edible vegetable oil, namely JO, RSO and KSO were procured from Vietnam through an authorized Malaysia based distributor, Kinetic Chemicals (M) Sdn.Bhd, while CO was purchased from Benua Sains Sdn. Bhd. Malaysia. All non-edible oils employed in this investigation were used as received without further purification except for WCO. WCO was purchased from a local university cafeteria at Seri Iskandar, Perak. The waste oil is filtered through a normal sieve by simple filtration and heated at a temperature of 110 ºC for 1 hr for moisture removal before stored in an airtight polystyrene container. All chemicals including methanol (99-100%), ethanol (99-100%), sodium hydroxide pellets (96%), potassium hydroxide pellets (>84%), phenolphthalein (pH 8.2-9.8), acetone (99%), sodium thiosulphate pentahydrate (99%), n-hexane (96%), hydrochloric acid (37%0, sulphuric acid (98%), isopropanol, starch, iodine, sodium iodine, glacial acetic acid and bromine were purchased from Merck. A standard mixture of 37 fatty acid methyl ester is used as the external standard mixture with varied weight percentages ranging from 2 to 4 wt. %. The nonadecanoic acid methyl ester internal standard was purchased from Sigma-Aldrich. All chemicals were analytical reagent grade.

2.2. Methods

All physio-chemical properties of non-edible oils are evaluated and studied under standard analytical methods established by American Oil Chemists' Society (AOCS) and American Society for Testing and Materials (ASTM). Each physio-chemical parameter was averaged at triplicates to ensure adequate reproducibility of results. For quantitative measure of free fatty acids in the oil, acid value is determined by a titration method using a standard solution of potassium hydroxide in ethanol according to the AOCS Te 1a-64. The unsaturation level of the lipid based feedstock is measured from iodine value using standard Wijs solution in accordance to AOCS Method Tg 1a-64. Density and kinematic viscosity of the oil were determined using density meter (DMA 4100 M series) and Ubebelohde viscometer (Tamson TVB445, ISL, France) respectively in reference of ASTM D 4502 and DIN 12058. Furthermore, a compact coulometric (C30, Karl Fischer,USA) was used to determine the moisture content of the oil following ASTM D 2709, whereas flash & fire point tester (CLA5, Petrotest) and bomb calorimeter (C5000, IKA Werke, Germany) were employed to determine the flash point and calorific heating value of the oil and measured according to ASTM D 93 and ASTM D 4568 respectively. For the fatty acid composition of each non-edible oil, the qualitative analysis was performed via High Temperature Gas-Chromatography (GC) – Mass Spectroscopy (MS) system, which consisted of an Agilent 7890 A GC with an injector. The fatty acid of the glycerides were esterified into methyl esters of the corresponding fatty acid and the deconvoluted FAME spectra were compared with the retention times of the external reference standard.

3. Results & Discussion

Table 1: Physio-chemical properties of non-edible oils

Parameters	Mean Standard Deviation (n = 3)					
	WCO	JO	CO	RSO	KSO	ASTM D-975 Diesel Fuel
Colour	Light Brown	Light Brown	Pale Yellow	Dark Brown	Pale Yellow	-
Molecular weight (g/mol)	821.99 ± 5.45	807.62 ± 4.75	941.11 ± 5.74	844.20 ± 5.68	867.61 ± 5.25	-
Density (g/cm^3) at 20 °C	0.92 ± 0.00	0.91 ± 0.00	0.92 ± 0.00	0.91 ± 0.00	0.92 ± 0.00	0.81-0.87
Viscosity (mm^2/s) at 40 °C	50.07 ± 0.08	39.15 ± 0.03	315.70 ± 0.02	40.71 ± 0.04	36.21 ± 0.05	1.5-5.8
Iodine value (mg/g)	54.74 ± 0.32	109 ± 2.70	130.12 ± 4.85	115 ± 3.40	97.75 ± 2.15	-
Flash point (°C)	301 ± 3	232 ± 5	285 ± 4	247 ± 3	215 ± 3	52
Calorific value (MJ/kg)	39.86 ± 0.04	39.70 ± 0.07	34.25 ± 0.08	39.95 ± 0.07	37.41 ± 0.05	-
Moisture content (wt. %)	0.10 ± 0.02	0.23 ± 0.01	0.33 ± 0.01	0.40 ± 0.00	0.25 ± 0.00	0.05
Acid value (mg KOH/g)	2.01 ± 0.04	21.56 ± 0.04	2.30 ± 0.03	85.07 ± 0.02	11.50 ± 0.05	0.25
FFA (%)	1.12 ± 0.02	10.87 ± 0.03	1.15 ± 0.01	41.55 ± 0.03	6.0 ± 0.2	-

3.1. Physio-chemical Properties

All physio-chemical properties of non-edible oils (WCO, JO, CO, RSO, and KSO) are characterized and presented in Table 1. With the standard ASTM D 975 diesel fuel specifications, a comparative study of properties is performed with the emphasis on their potential use as renewable fuel production feedstock. Despite the inherent similarity in chemical structure, each oil has its own physical and chemical characteristics with distinct variation in fatty acid composition, degree of saturation and of other physical elements.

3.2. Density

In general, the densities of WCO, JO, CO, RSO and KSO fall in the range of 0.91-0.92 g/cm^3, which are slightly lower than that of water. In this study, RO and JO have the lowest density of 0.91g/cm^3 in contrast to WCO, CO and KSO. The results are in accord with those reported in previous studies [6, 7, 26]. It has been reported that density of oil increases linearly with carbon chain length, molecular mass and saturation level. Surprisingly, all densities of vegetable oils reported here did not show any significant variation with molecular mass and saturation level. From Table 1, it can be observed that the density variation of all non-edible vegetable oil are relatively small and comparable to each other. Despite the small variation, the densities reported are slightly higher than the standard diesel fuel oil specifications (0.81-0.87 g/cm^3). This could be mainly attributed to the presence of contaminants in the oils and can be improved through pre-bleaching method in removing impurities particles such as pigments, non-hydrated lecithin, oxidized fats and other non-lip materials.

3.3. Kinematic Viscosity

From Table 1, all kinematic viscosities of non-edible vegetable oils are deviated largely from the standard diesel fuel oil specification ranges between 1.5mm^2/s to 5.8 mm^2/s at 40ºC. These results are in good agreement with those concluded in previous studies, where neat vegetable oil is not suitable to be incorporated directly into the existing vehicular engines due to its inherent high viscosity characteristic [19]. The highly viscous vegetable oil adversely affecting the proper operation mechanism of fuel spray injector and efficiency of fuel atomization for airless combustion system. Among the non-edible vegetable oil studied, castor oil found to be much more viscous than the other vegetable oils and its viscosity is approximately fiftyfold higher than that of diesel fuel specification. Such result corroborates with the finding of Okullo, et al. [17], who found out that castor oil has a viscosity up to tenfold higher than that of other vegetable oil. It is worthy to take note that castor oil has the largest and heaviest molecular mass of 941 g/mol, which further confirmed the linear relationship between oil viscosity and molecular weight. The high molecular mass of castor oil is mainly attributed to exceptionally high level of ricinoliec acid and the strong hydrogen bonding between hydroxyl groups of fatty acid molecules [17]. Furthermore, the viscosity of waste cooking oil is relatively higher than the remaining three neat vegetable oils (JO, RSO & JSO). It has been reported that waste cooking oil has a higher viscosity than the fresh vegetable oil due to the accumulation of volatile and non-volatile compounds present in the oils after prolonged cooking process [1]. The unenviable viscous property of neat vegetable oil feedstock may not be tolerated in industrial renewable fuel industry with high pumping power requirement and the resistance to flow freely through pipeline or catalyst bed at low temperature. To enhance its flowing characteristics, solvent dilution is highly recommended in reducing the oil viscosity before processing [17].

3.4. Moisture Content

Moisture content is one of the key factors in determining the storage lifespan of the feedstock. Low moisture content indicates good shelf life characteristic, whereas high moisture content in the feedstock reduces the heat of combustion. Furthermore, presence of moisture content in the oil will serve as a medium for microbial colonies growth and promotes severe plug-up and corrosion of storage tank system. In this study, all oil's moisture contents are found to be exceeded the maximum moisture limit stated in the standard diesel fuel oil specifications. From Table 1, it can be observed that RSO has the highest moisture content, which is in line with the previous studies conducted by Yusup & Khan [31]. Conversely, WCO has the lowest moisture content as most of the water content present in the oil is evaporated through multiple cycle of cooking processes. For industrial renewable fuel production, the vegetable oils can be stored in a nitrogen blanket storage tank to inhibit microbial growth and the moisture content can be easily removed under preheating treatment before feeding into the hydro-processing process [7].

3.5. Flash Point

For safety requirement in handling and storage of raw feedstock, high flash point is mandatory to prevent any possible fire and explosion threats. Generally, flash point is the lowest temperature at which the combustible fuel emits adequate vapour to form an ignitable mixture on an application of an ignition source under standard conditions. It is an indication of flammability risk and a measure of the volatility of a fuel. Flash point temperature usually varies inversely with the fuel's volatility. The lower the flash point temperature, the higher the fuel flammability, the easier the fuel to ignite under standard conditions. In accordance to the standard ASTM D 975 diesel fuel oil specification, fuels with flash point above 52^{o}C are classified as safe fuels with low flammability. It can be observed that all flash points of the oil are ranges between 215 ^{o}C and 300^{o}C, which are well above the 52^{o}C minimum ASTM recommended range and therefore pose no risk of fire outbreaks in case of accidents. From Table 1, it can be seen that CO and WCO have relatively high flash point temperature, rendering them safer to handle and store as raw liquid feedstock.

3.6. Calorific Value

For calorific values, the heat of combustion of all non-edible oils are comparatively similar to each other, but far lower than the conventional diesel fuel calorific value, 44.8 MJ/kg. (Sara, et al., 2011) RSO has the highest calorific value with 39.95 MJ/kg, closely followed by WCO and JO and lastly CO. The low calorific value of castor oil can be elucidated in the context of fatty acid composition as it has the highest quantities of ricinoleic fatty acid, at which the fatty acid consists of hydroxyl groups on its triglycerides structure.

3.7. Iodine Value

Iodine value is an index of unsaturation degree of fatty acid. A higher iodine value indicates higher unsaturation of oils. In hydroprocessing, hydrogen gas is usually employed as a hydrogenation reactant in saturating the olefin present in the triglyceride structure. According to a team of petroleum refinery development experts from Haldor Topsoe and Preem, molecular hydrogen consumption in hydrotreating renewable feed can be reached up as high as 200 Nm^3 hydrogen/ m^3 liquid feed, even co-processing triglycerides feedstock at the lowest percentage [8]. That is twice as much as that is required for hydroprocessing conventional fossil diesel oil, which is approximately around 100 Nm^3/ m^3 [10]. Thus, low unsaturation level in the triglyceride feedstock will result in low hydrogen consumption. Among the five non-edible oil, waste cooking oil has the lowest unsaturation level with minimum amount of double bonds.

3.8. Acid Value

Acidity of the triglyceride feedstock is mainly attributed to the unesterified long chain free fatty acid formed from hydrolytic reaction. In typical industrial processing plant, high acidity feedstock involves the necessity to incorporate stainless steel pipeline system to prevent metal corrosion. However, such material can be replaced by fiber glass reinforced plastic (FRP), which is far more durable, lighter and cheaper in contrast to stainless steel. High acidity in fuel product is usually undesirable due to the potential of corroding major fuel supply system and internal combustion components. From hydro-processing process perspective, high level of free fatty acid can reduce the severity of processing conditions significantly due to the accessibility to transform the carboxylic acid into fuel hydrocarbon without undergoing hydrolysis of triglycerides or scission of glycerol from the triglyceride structure. In this study, the acidity of the non-edible oils were found to be very high, exceeded the maximum acceptable limits of

0.25 mg/KOH/g recommended by standard ASTM D975 . It can be observed that RSO and JO have the highest acid values, which are consistent with the exceptionally high level of free fatty acid present. Despite the high acidity level, both oils are suitable to be used as the renewable diesel feedstock due to its enhancement of the availability of free fatty acid, which typically requires severe process conditions in yielding such compounds from triglycerides.

3.9. Fatty Acid Profile

The fatty acid composition of WCO, JO, CO, RSO and KSO are presented as shown in Table 2. All non-edible oil below are classfied into three types: saturated, monosaturated and polysaturated fatty acids. The fatty acid composition of each oils are in good agreement with those observed in previous characterization studies [30]. In renewable diesel production, saturated fatty acid is more favorable than monosaturated and polysaturated fatty acids due to the unnecessity to saturation of olefin bonds. Among the non-edible oils, WCO and RO have the lowest unsaturated fatty acid content, in contrast to JO, CO and KSO with unsaturated fatty acid content up to 93.3%.

Table 2: Fatty Acid Profiles of Non-Edible Oil

Parameters			Mean Standard Deviation (n = 3)				
			Waste Cooking Oil	Jatropha Oil	Castor Oil	Rubber Seed Oil	Kapok Seed Oil
Fatty acid composition (wt. %)	Myristic acid	C14:0	0.9 ± 0.0	2.5 ± 0.2	-	-	-
	Palmitic acid	C16:0	36.7 ± 0.6	10.5 ± 0.2	1.4 ± 0.3	13.7 ± 0.2	28.5 ± 0.1
	Stearic acid	C18:0	6.5 ± 0.3	3.3 ± 0.5	0.9 ± 0.6	10.8 ± 0.3	5.0 ± 0.4
	Arachidic acid	C20:0	-	-	-	-	3.5 ± 0.5
	Oleic acid	C18:1	44.7 ± 0.5	54.2 ± 0.3	4.5 ± 0.5	25.2 ± 0.6	23.0 ± 0.2
	Ricinoleic acid	C18:1	-	-	87.9 ± 0.4	-	-
	Linoleic acid	C18:2	11.2 ± 0.1	29.5 ± 0.1	5.3 ± 0.1	34.0 ± 0.7	40.0 ± 0.1
	Linolenic acid	C18:3	-	-	-	16.3 ± 0.5	-

3.10. Feedstock Availability

Feedstock selection is one of the pivotal aspects closely affecting the overall complexity of production route, severity of the operating conditions and the total profitability of renewable fuel production. According to Phan & Phan [18], comprehensive selection of bio-energy feedstock is essential as the raw material cost can reach up as high as 75 % of the total bio-fuel production expenditure. To enhance the feasibility in commercialize such renewable fuels production in Malaysia, the raw feedstock must be available locally in abundance quantities. According to Ministry of Plantation Industries and Commodities Malaysia (MPIC), Malaysia owns a total of 8.73 million hectares of agricultural land widely distributed throughout the 13 states, at which all of that land are cultivated with a wide variety of energy crops such as oil palm, rubber seed oil, coconut, cocoa and others [11].

Among the diverse agriculture crops available in Malaysia, oil palm is one of the most versatile and oil productive producing crops widely grown in many states, mostly in East Malaysia (Sabah and Sarawak). It is the leading agricultural crops in Malaysia, occupying 5.4 million hectares (82 per cent) of the total cultivated plantation area. In fact, Malaysia is the world's largest producer and exporter of palm oil today followed by Thailand and Indonesia, contributing over 49.5 % of world production and 64.5% of world exports [14]. Utilization of such abundant oil resource as the feedstock has a bright potential in producing a sustainably renewable energy source due to its vast availability and sustainability in Malaysia. However, direct upgrading of edible palm oil to fuels in a continuous and large-scale production would result in negative impacts on the local food supply chain and causing undesirable rising food prices. To resolve such food versus fuel debate, waste cooking oil derived from palm olein can be one of the sustainable feedstock alternative since it is non-edible and unsuitable for human consumption due to the presence of toxic carcinogenic elements in the oils after multiple cycles of usage. With the radical population growing rate in Malaysia, palm oil based WCO is produced at an unprecedented volume and it has been reported that 0.12 metric ton of WCO is available annually from Malaysian residential householders, commercial food businesses and fast food franchises [7]. However, locally available WCO resources are very challenging to collect due to the absence of proper collection system, which is yet to be introduced and implemented in Malaysia.

Besides palm oil, the second largest agricultural plantations widely grown in Malaysia are rubber seed trees (*Hevea Brasiliensis*) which covers more than 1.2 million hectares all over Malaysia [11]. Malaysia is globally renowned for its high quality and competitively priced rubber products, such as medical gloves, automotive components, hoses and structural bearings. Malaysia remains as the world's leading supplier for medical gloves, satisfying over 50% of the global demands by exporting a wide range of rubber products to 190 countries globally [13]. Generally, each rubber trees grows about 500g of oil seeds per annum and this works out to an estimated availability of 150 kg of rubber seeds per hectares [15]. It has been found out that the tree seeds yield a good amount of oil, ranging in between 50wt% to 60wt% and the kernel shell contain up to 50wt% of brown color oil [13]. So far, there is no major industrial applications could be found with the underutilized rubber seed oils. With a total 1.2 of million hectares rubber tree plantation available in Malaysia, the RSO feedstock capacity can reach up to 60 million ton per annum with an estimated oil yield of 50 kg oil/ha/year, which is 500-fold more than that the annual waste cooking oil available in Malaysia.

Other than WCO and RSO, Jatropha tree is another prospective oil bearing plantation crop which hold great promises and potential to serve as a renewable feedstock for biofuel production in Malaysia. The extracted Jatropha oil is essentially non edible for human population due to the presence of anti-nutritional compounds in the oil. As more and more Southeast Asia countries such as Thailand, Indonesia, Myanmar and Laos are tapping into Jatropha bandwagon, the sub-tropical crops are progressively drawing substantial attentions and interests from many agricultural parties in Malaysia due to its inherent high oil yield, excellent growth adaptability with limited nutrients and unique ecological features. So far, the development of commercial Jatropha crop plantations in Malaysia is still at a nascent stage, at which Malaysia government has no immediate plan in cultivating Jatropha crops at commercial basis due to the existing palm oil plantation equilibrium, shortage of low cost labors and the disinclination to lose out any opportunity offered by the emerging biodiesel industry.

Despite the slow development of Jatropha cultivation process, active research and development (R&D) projects have been intensively carried out in partnership with numerous Malaysian government agencies such as Ministry of Plantation Industries and Commodities (MPIC), Malaysian Rubber Board (MRB) and National Tobacco Board. Most of the R&D activities aim to assess and evaluate the agronomic potential and growth performance of Jatropha crop at various locations in Malaysia. For instance, MPIC has appointed MRB and Sabah Land Development Board (SLDB) as the national bodies in cultivating this perennial shrub at a pilot scale in Kota Marudu, Sabah [11]. Up to 2015, it has been reported that Malaysia has a total of 259,906 hectares of Jatropha crops plantation and the existing crops are capable of producing 4.27 ton/ha/year of dry seeds [11,25]. However, it is expected that the present Jatropha crop plantation capacity is still inadequate to be incorporated as the prospective bioenergy feedstock in Malaysia as the cultivation of Jatropha crops is still very new to Malaysia agricultural sector.

Furthermore, castor is another essential non-edible oilseed crop with great utilitarian value in Malaysia agriculture sector. This non-edible oilseed crop has the potential to yield up to 4-5 tons per hectare, resulting a total maximum of 2000 kg/ha of oil. In Malaysia, *Casa Kinabalu Sdn.Bhd* is the only private owned agricultural company fully committed to the castor crop cultivation and oil production. The newly established company has a total of 2865 hectares castor crop plantations widely distributed in Sarawak, Negeri Sembilan, Johor and Kedah [28]. The company anticipated to expand the castor crop plantations to 20,000 hectares in 2020. However, all the castor seeds harvested by the company are exported to China, which in turn limits its potential as renewable fuel feedstock. For KSO, the statistics on the exact plantation area are limited and scarceness in open literature. The potential for this oil to be employed as feedstock seems rather despairing as well, mainly attributed to lack of financial and incentive supports from Malaysian government.

4. Conclusion

With a fairly humid and tropical warm climate marked by seasonal variation in rainfall, Malaysia has an advantageous edge in driving agricultural farming sector forward by exploiting the oil bearing vegetable crops as the renewable diesel production feedstock. Among the non-edible oil available in Malaysia, RSO has the brightest potential in satisfying the emerging local bioenergy industry due to its existing large cultivation area in Malaysia. It has the most desirable physio-chemical properties for renewable diesel production. Successful introduction of renewable diesel into Malaysia vehicular fuel market would greatly alleviate national dependence on fossil fuels and accelerates Malaysia aspiration in reducing the carbon emission to 45% by 2030.

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